AMENDMENT TO THE CLAIMS

This listing of claims will replace all prior versions, and listings, of claims in the application:

LISTING OF CLAIMS

1 – 120 (cancelled)

121. (new) A geometric pattern matching apparatus for refining a starting pose of an object in a run-time image, the object having an expected shape and a true pose in the run-time image, the starting pose representing an initial estimate of the true pose of the object in the run-time image, the apparatus comprising:

a stored model pattern, the stored model pattern including a geometric description of the expected shape of the object, the geometric description including a plurality of pattern boundary points, and information about the pattern boundary points; and

a run-time module adapted to:

receive the stored model pattern, the starting pose, and the run-time image;

detect in the run-time image a plurality of image boundary points; and

use the stored model pattern, the starting pose, and the plurality of image boundary points in a sequence of pose refinements to provide: a refined pose, the refined pose representing a refined estimate of the true pose of the object in the run-time image; an error value; an aggregate clutter value; and an aggregate coverage value.

122. (new) The apparatus of claim 121, wherein the run-time module is also adapted to provide:

provide an evaluated image boundary point list that provides, for each of a plurality of said image boundary points, a numerical evaluation of the likelihood that the image boundary point was present in the stored model pattern.

123. (new) The apparatus of claim 121, wherein the run-time module is also adapted to provide:

an evaluated pattern boundary point list that provides, for each of a plurality of said pattern boundary points, a numerical evaluation of the likelihood that the pattern boundary point was present in the run-time image.

124. (new) The apparatus of claim 121, wherein the run-time module is also adapted to:

receive and use a coordinate transformation that maps points in an orthonormal coordinate system to points in the run-time image.

125. (new) The apparatus of claim 121, wherein the run-time module is also adapted to:

determine, using the starting pose and the model pattern, an evaluation of reliability of at least some of the plurality of image boundary points, and a corresponding position along a boundary of the model pattern corresponding to at least some of the plurality of image boundary points.

126. (new) The apparatus of claim 121, wherein parameters are used to help detect in the run-time image a plurality of image boundary points.

127. (new) The apparatus of claim 121, wherein parameters are used to facilitate the sequence of pose refinements.

128. (new) The apparatus of claim 121, wherein the error value is an rms error value.

129. (new) The apparatus of claim 121, wherein the information about the pattern boundary points is a vector-valued function of position within a region that includes the pattern boundary points.

130. (new) The apparatus of claim 129, wherein the vector-valued function relates a plurality of at least two-dimensional positions to a plurality of respective displacement vectors.

131. (new) The apparatus of claim 130, wherein each displacement vector indicates a distance and direction from a two-dimensional position to a nearest point along a pattern boundary that includes pattern boundary points.

132. (new) The apparatus of claim 129, wherein the vector-valued function relates a plurality of two-dimensional positions and associated directions to a plurality of respective displacement vectors.

133. (new) A geometric pattern matching apparatus for refining a starting pose of an object in a run-time image, the object having an expected shape and a true pose in the run-time image, the starting pose representing an initial estimate of the true pose of the object in the run-time image, the apparatus comprising:

a stored model pattern, the stored model pattern including a geometric description of the expected shape of the object, the geometric description including a plurality of pattern boundary points, and information about the pattern boundary points;

a feature detector adapted to detect in the run-time image a plurality of image boundary points; and

a sequential pose refinement module adapted to use the stored model pattern, the starting pose, and the plurality of image boundary points in a sequence of pose refinements to provide:

a refined pose, the refined pose representing a refined estimate of the true pose of the object in the run-time image;

an error value;

an aggregate clutter value; and

an aggregate coverage value.

134. (new) The apparatus of claim 133, wherein the sequential pose refinement module receives and uses a coordinate transformation that maps points in an orthonormal coordinate system to points in the run-time image.

135. (new) The apparatus of claim 133, wherein the sequential pose refinement module also being adapted to provide an evaluation of reliability of at least some of the plurality of image boundary points, and a corresponding position along a boundary of the model pattern corresponding to at least some of the plurality of image boundary points.

136. (new) The apparatus of claim 133, wherein the sequential pose refinement module also being adapted to provide an evaluated image boundary point list that provides, for each of a plurality of said image boundary points, a numerical evaluation of the likelihood that the image boundary point was present in the stored model pattern.

137. (new) The apparatus of claim 133, wherein the sequential pose refinement module also being adapted to provide an evaluated pattern boundary point list that provides, for each of a plurality of said pattern boundary points, a numerical evaluation of the likelihood that the pattern boundary point was present in the run-time image.

138. (new) The apparatus of claim 133, wherein the feature detector uses parameters to help detect in the run-time image the plurality of image boundary points.

139. (new) The apparatus of claim 133, wherein the sequential pose refinement module uses parameters to facilitate the sequence of pose refinements.

140. (new) The apparatus of claim 133, wherein the error value is an rms error value.

141. (new) The apparatus of claim 133, wherein the information about the pattern boundary points is a vector-valued function of position within a region that includes the pattern boundary points.

142. (new) The apparatus of claim 141, wherein the vector-valued function relates a plurality of at least two-dimensional positions to a plurality of respective displacement vectors.

143. (new) The apparatus of claim 142, wherein each displacement vector indicates a distance and direction from a two-dimensional position to a nearest point along a pattern boundary that includes pattern boundary points.

144. (new) The apparatus of claim 141, wherein the vector-valued function relates a plurality of two-dimensional positions and associated directions to a plurality of respective displacement vectors.

145. (new) A geometric pattern matching method for refining a starting pose of an object in a run-time image, the object having an expected object boundary and a true pose in the run-time image, the starting pose representing an initial estimate of the true pose of the object in the run-time image, the method comprising:

providing model pattern boundary information of a model pattern of the object;

providing an image boundary description of an object boundary in the run-time image; and

using the model pattern boundary information, the starting pose, and the image boundary description in a sequence of pose refinements to provide at least a refined pose, the refined pose representing a refined estimate of the true pose of the object in the run-time image.

146. (new) The method of claim 145, wherein providing an image boundary description of a boundary in the run-time image includes:

detecting in the run-time image a plurality of image boundary points.

147. (new) The method of claim 145, wherein providing an image boundary description of a boundary in the run-time image includes:

synthetically generating a plurality of image boundary points.

148. (new) The method of claim 145, wherein using the model pattern boundary information, the starting pose, and the image boundary description in a sequence of pose refinements further provides an error value.

149. (new) The method of claim 145, wherein using the model pattern boundary information, the starting pose, and the image boundary description in a sequence of pose refinements further provides an aggregate clutter value.

150. (new) The method of claim 145, wherein using the model pattern boundary information, the starting pose, and the image boundary description in a sequence of pose refinements further provides an aggregate coverage value.

151. (new) The method of claim 145, wherein providing model pattern boundary information of a model pattern of the object includes:

providing a stored model pattern, the stored model pattern including a geometric description of the expected shape of the object, the geometric description including a plurality of pattern boundary points, and information about the pattern boundary points.

152. (new) The method of claim 151, wherein the information about the pattern boundary points is a vector-valued function of position within a region that includes the pattern boundary points.

153. (new) The method of claim 152, wherein the vector-valued function relates a plurality of at least two-dimensional positions to a plurality of respective displacement vectors.

154. (new) The method of claim 153, wherein each displacement vector indicates a distance and direction from a two-dimensional position to a nearest point along a pattern boundary that includes pattern boundary points.

155. (new) The method of claim 152, wherein the vector-valued function relates a plurality of two-dimensional positions and associated directions to a plurality of respective displacement vectors.

156. (new) The method of claim 145, wherein providing model pattern boundary information of a model pattern of the object includes:

providing a geometric description of the expected shape of the object.

157. (new) The method of claim 156, wherein the geometric description includes a plurality of pattern boundary points.

158. (new) The method of claim 145, wherein providing model pattern boundary information of a model pattern of the object includes:

providing a plurality of pattern boundary points, and information about the pattern boundary points.

159. (new) The method of claim 151, wherein each pattern boundary point of the plurality of pattern boundary points includes:

position information and direction information.

160. (new) The method of claim 146, wherein each image boundary point obtained by detecting in the run-time image a plurality of image boundary points includes:

position information and direction information.